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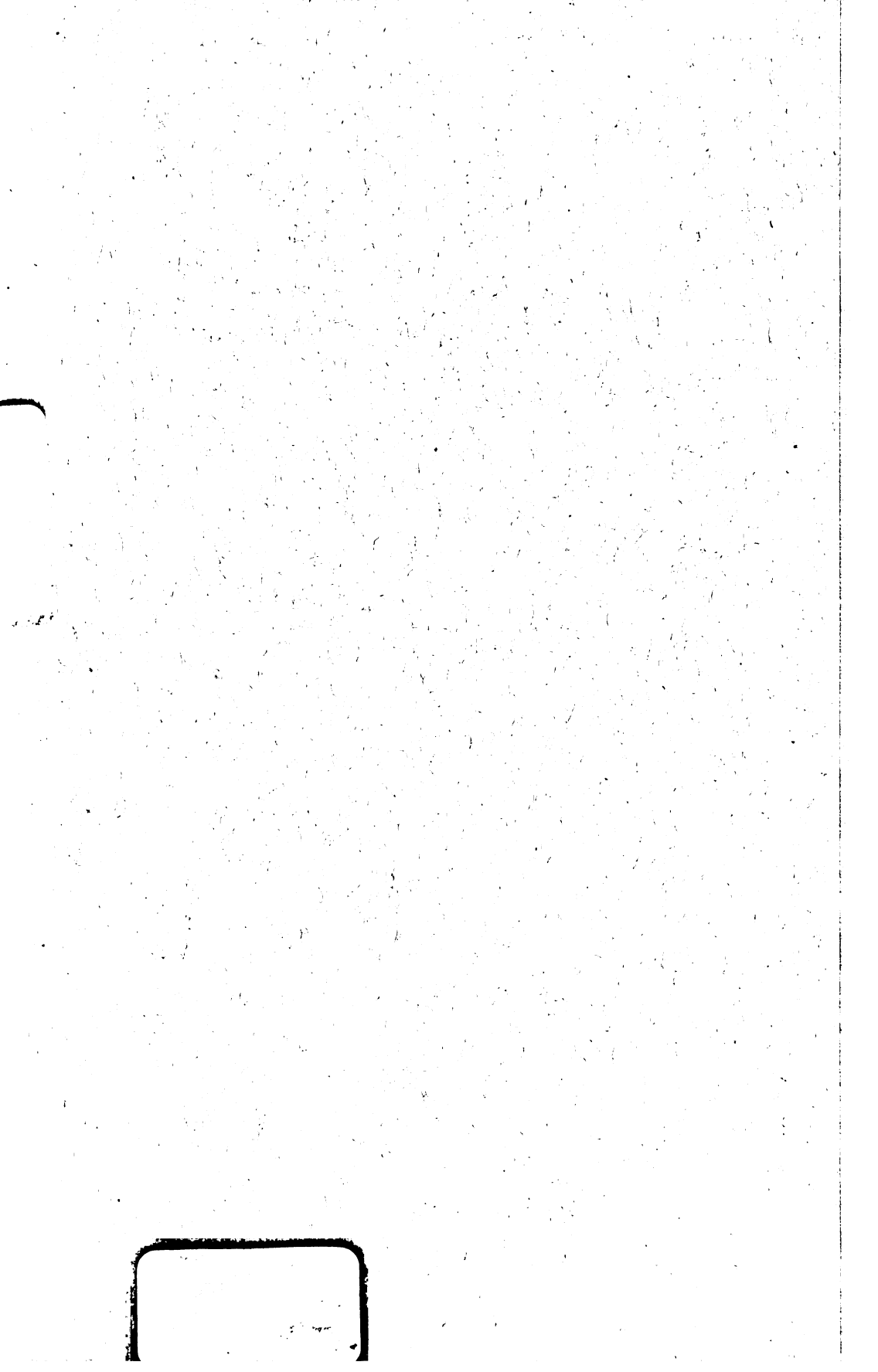
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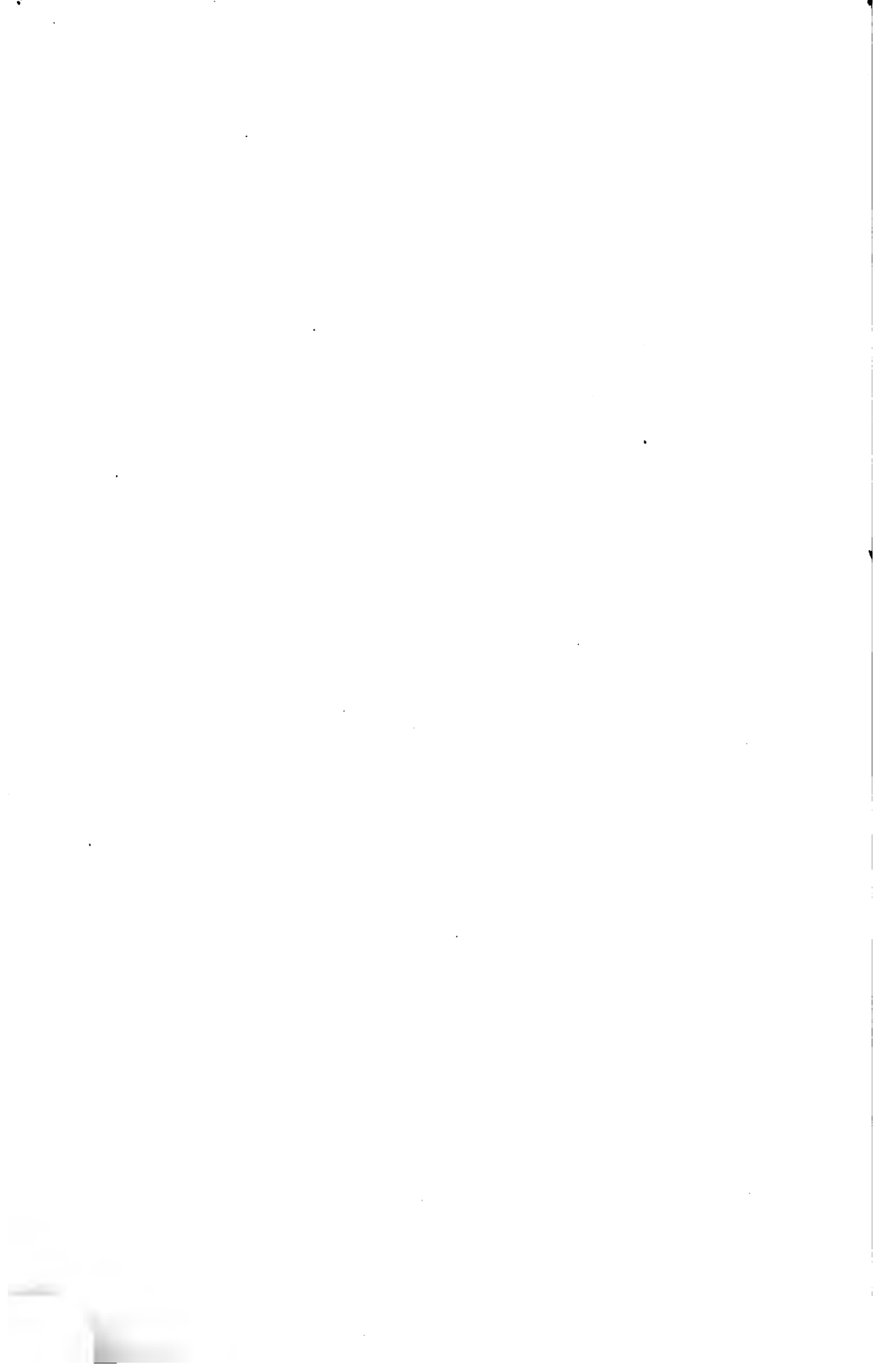


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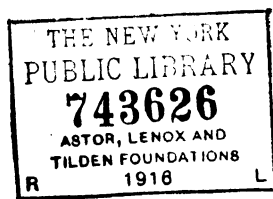
PREHISTORIC BRONZE IN SOUTH AMERICA.

BY
CHARLES W. MEAD.

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INTRODUCTION.

The principal object of this paper is to put on record the results of one hundred and sixty analyses of prehistoric copper and bronze objects from Peru and Bolivia. These analyses were made for the American Museum of Natural History by Mr. W. A. Wissler. Also six specimens analyzed for the Museum by Doctors Morris Loeb and S. R. Morey, and five specimens analyzed by Professor S. P. Sharples for the Peabody Museum, Harvard University, for which I am indebted to the kindness of Professor F. W. Putnam.

The figures show most of the forms of objects from which samples of metal have been taken for these analyses.

In the following tables the amount of copper and tin is given. It was not considered important to determine the exact amount of the other metals, but their presence or absence is noted. For convenience, chemical symbols have been used.¹

Mr. Wissler reports on his analyses, as follows:—

The table consists of analyses made at the American Museum of Natural History of prehistoric bronze and copper specimens from South America, to determine whether the addition of tin was intentionally and scientifically made.

Owing to the small amount of drillings taken for the analyses, in some cases only .07 gram, the results should be taken as a close approximation of the true composition.

Tin was determined as stannic oxide, by the method of Busse. In all cases where the total precipitate weighed less than 15 mg. it was weighed as such. If there was more than this amount the precipitate was fused with caustic potash and the tin determined electrolytically. Copper was determined by iodometry, excepting that in all cases where the total amount was less than .15 gm. it was determined electrolytically.

Qualitative tests were made by the Johnson-Marsh test for arsenic and antimony, dimethyl glyoxime for nickel, and the ordinary routine methods for the other metals. Tin was detected by the presence of the oxide after solution in nitric acid, and was found to appear plainly and certainly when present to the amount of .00001 gram. The table records all tests made, whether with positive or negative results.

In some cases, as for example in catalogue numbers 9195 and 9188, the specimens were so corroded that the initial weight of the sample was discarded, a complete analysis made, and the total weight of the metals found taken as the true weight.

Numbers 3114 and 5166 are distinctly estimates, probably correct within one percent of the true analysis. In numbers 2486, 760, 4599, 7791, 9193, 9205, 9194, 9198, 2821a, 2644, 9199, 2792b, 2800, 2639, 9191, 9190, 2791a, 2804, 2821b, 9208, 857, 858, 860, 6584, 9187, 4265, 2791b, 2821c, 1819, 1955, 5192d, 9189, 1961, 2094, 1965,

¹ Cu, copper; Sn, tin; Pb, lead; Ag, silver; As, arsenic; Sb, antimony; Ni, nickel; Zn, zinc; S, sulphur; Au, gold; Fe, iron.

1807, 1998, 2068, 9206, 2643, 9210, 1834, 1806 copper was determined by difference after the absence of other metals had been established.

In several cases the absence of lead has been marked with a question mark, as at the time it was not considered necessary to test for it, but if present it would very probably have been noticed in the method of analysis used.

In a paper by Doctors Loeb and Morey, read at the December (1909) meeting of the American Chemical Society the six specimens analyzed by them for the Museum are thus described:—

It will be seen that these metals differ remarkably in composition, and indicate the possession of considerable metallurgical skill by the inhabitants of that region. The absence of the slightest traces of silver may be taken as a proof that the tin was derived from cassiterite, rather than native tin. The specimen, catalogue number 859 (this is the socketed spear point from Chan Chan on the northern coast), suggests its preparation from domekite, or some other copper arsenide, fairly free from sulphur. Owing to the small mass of samples, which were drilled or cut from the specimens, the density determinations, made with water in a pycnometer, are only approximate. In specimen, catalogue number 1949, a cast chisel with characteristic air-holes or "pipes," the porosity of the material undoubtedly occasioned a low result. Tin and copper were separated by potassium polysulphide, the former determined as stannic oxide and the latter electrolytically. Arsenic was separated from copper by Crookes' method, and sulphur was weighed as barium sulphate after oxidation with nitric acid in a sealed tube.¹

Of these six objects five come from the Island of Titicaca, Bolivia. They all contain tin, the average being 6.59 percent. The spear point comes from Chan Chan on the northern coast and contains no tin.

¹ *Journal of the American Chemical Society*, vol. XXXII, No. 5, May, 1910.

ANALYSES.

TABLE I. BY W. A. WISSLER.

PERU.

Cat. No.	Locality.	Object.	Cu.	Sn.	Present.	Absent.
5151	Chepen.....	Agricultural impl.....	.....	.....	Cu.....trace Fe.	Sn., Pb., Ag., As., Sb., Ni., Zn.
5152	".....	".....	.....	.....	Cu.....trace Fe.	Sn., Pb., Ag., As., Sb., Zn.
5153	".....	".....	.....	.....	Cu.....	Sn., Pb., Ag., Ni., Zn.
5154	".....	".....	.....	.....	Cu.....trace Sn.?	.....
5155	".....	".....	.....	.....	Cu.....	Sn., S.
5156	".....	".....	.....	.....	Cu.....	Sn.
5157	".....	".....	.....	.....	Cu.....trace Fe.	Sn., Pb., Ag., Sb., Ni., Zn.
5158	".....	".....	.....	.....	Cu.....trace Fe.	Sn., Pb., Ag., Ni., Zn.
5159	".....	".....	.....	.....	Cu.....	Sn., Ag., Pb., S.
5160	".....	".....	.....	.....	Cu.....	Sn., Ag., Pb., Fe., Zn.
5161	".....	".....	.....	.....	Cu.....	Sn.
5162	".....	".....	.....	.....	Cu.....	Sn.
5163	".....	".....	.....	.....	Cu.....trace Fe.	Sn., Pb., Ag., As., Sb., Ni., Zn.
5164	".....	".....	.....	.....	Cu.....	Sn., Zn.
5165	".....	".....	.....	.....	Cu.....trace Fe.	Sn., Ag., Pb., Sb., As., Ni., Zn.
5166	".....	".....	.....	.....	Cu.....	Sn., Ag., Pb., Sb., Fe., Zn.
5167	".....	".....	.....	.....	Cu.....trace Sn.?	Ag., Zn.
5168	".....	".....	.....	.....	Cu.....	Sn.
5170	".....	".....	.....	.....	Cu.....	Sn.
5171	".....	".....	.....	.....	Cu.....	Sn.
5172	".....	".....	99.62	.015	S (.265).....	.....
5196	".....	Chisel.....	.....	.....	Cu.....	Sn.
5198	".....	Chisel or Ax.....	.....	.....	Cu.....	Sn.
5184	".....	Chisel.....	98.45	1.04	.....	Pb.?
5197b	".....	Knife.....	.....	.....	Cu.....	Sn.
5197a	".....	".....	.....	.....	Cu.....trace Sb.	Sn.
5197h	".....	".....	.....	.....	Cu.....	Sn.

5197l	"	.....	"	.....	96.13	3.54	.....	Ag., Pb., S.
5195	"	.....	"	.....	92.00	7.98	.....	Pb.
5193	"	.....	"	.....	.....	.....	Cu.....	Sn.
5192e	"	.....	"	.....	.....	.....	Cu.....	Sn.
5197k	"	.....	"	.....	96.68	.....	.....	Sn., Pb.
5191	"	.....	"	.....	98.61	.....	.....	Sn., Pb.
5176	"	.....	"	.....	98.25	.....	trace Sn.....	Pb.
5148	"	.....	Trowel.....	.....	.....	.....	Cu.....	Sn.
5175	"	.....	"	.....	.....	.....	Cu.....	Sn.
5150	"	.....	"	.....	.....	.....	Cu.....	Sn.
5174	"	.....	"	.....	.....	.....	Cu.....	Sn.
5179	"	.....	"	.....	.....	.....	Cu.....	Sn.
5198	"	.....	Sheet copper.....	.....	.....	.....	Cu.....	Sn.
5191c	"	.....	"	.....	.....	.....	Cu.....	Sn.
5192d	"	.....	"	.....	.....	.....	Cu.....	Sn.
5169	"	.....	Spear point	.....	.....	.....	Cu.....	Sn.
5199	"	.....	"	.....	.....	.....	Cu.....	Sn.
5194k	"	.....	Cutting or digging impl.	.....	98.60	.....	Cu.....	Ag., Pb., S.
5192e	"	.....	"	.....	96.01	3.77	.....	Sn.
5218d	"	.....	Fragment.....	.....	.....	.....	Cu.....	Sn.
5200	"	.....	Nugget.....	.....	.....	.....	Cu.....	Sn.
5197i	"	.....	Cutting implement.....	.....	.....	.....	Cu.....	Sn., Pb., Zn.
5191g	"	.....	"	.....	.....	.....	Cu.....	Sn., Pb., Zn.
5194a	"	.....	"	.....	98.71	.....	Cu.....	Sn.
816	Trujillo	.....	Agricultural impl.....	.....	.....	.....	Cu.....	Sn.
855	"	.....	"	.....	.....	.....	Cu.....	Sn.
856	"	.....	"	.....	.....	.....	Cu.....	Sn.
857	"	.....	Spear point.....	.....	.....	.....	Cu.....	Sn., Ag., Pb., S.
860	"	.....	"	.....	.....	.....	Cu.....	Sn., Ag., Pb., S.
858	"	.....	"	.....	.....	.....	Cu.....	Sn., Ag., Pb., S.
4264	"	.....	"	.....	.....	.....	Cu.....	Sn.

PERU (Continued).

Cat. No.	Locality.	Object.	Cu.	Sn.	Present.	Absent.
4265	Trujillo.....	Spear point.....	.....	.....	Cu.....	Sn., Ag., Pb., S.
4291	Chimbote.....	Agricultural impl.....	.....	.....	Cu.....	Sn.
4292	"	"	93.04	7.01	.....	Pb., S.
4293	"	"	96.00	4.00	.....	.....
9349	"	"	94.71	4.57	trace Au., Fe.....	Pb., Ag., Ni., Zn.
9350	Chancay.....	Chisel.....	97.18	2.81	.....	Pb.?
9193	Cuzco.....	Knife.....	92.15	7.45	trace S., Pb.?	Ag.
9194	"	"	91.50	8.53	.....	Pb.?
9195	"	"	92.00	7.98	.....	Pb.?
9196	"	"	93.94	5.76	.....	Pb.?
9187	"	Ax.....	92.80	7.14	.....	.....
9188	"	"	95.84	3.87	.....	Pb.?
9202	"	Chisel.....	94.61	4.23	.....	Pb.?
9198	"	Topo.....	95.00	4.96	.....	Ag., Pb., S.
9199	"	"	95.36	4.58	.....	Pb., Zn.
9190	"	Llama figure.....	91.50	8.54	.....	Ag., Pb., S.
9189	"	"	98.00	2.02	.....	Ag., Pb., S.
9205	"	Deer figure.....	96.19	3.71	.....	Ag., Pb., S.
9191	"	Bola.....	90.05	9.64	.....	Ag., Pb., S.
9206	"	Human figure.....	97.80	2.15	.....	Ag., Pb., S.
9208	"	"	98.00	1.97	.....	Ag., Pb., S.
9210	"	"	.....	.....	trace Pb.?	Ag., S.
4291	Chimbote.....	Agricultural impl.....	.....	.....	Cu., Ag., trace S.....	Sn.
4292	"	"	93.04	7.01	Cu.....	Sn.
4293	"	"	96.00	4.00	.....	Pb., S.
9349	"	"	94.71	4.57	.....	.....
9350	Chancay.....	Chisel.....	97.18	2.81	trace Au., Fe.....	Pb., Ag., Ni., Zn.

9615	Cajamarca	Knife	94.33	5.67	
9196	"	"	93.94	5.76	
4598	Ancon	Chisel	94.90	5.16	
4599	"	"	94.38	5.62	
1253	Surco	"			Cu. Sn.

BOLIVIA.

Cat. No.	Locality.	Object.	Cu.	Sn.	Present.	Absent
2791a	Tiahuanaco	Knife	93.80	6.17		Ag, Pb., S.
2791b	"	"	94.50	5.43		
2794	"	"	92.11	7.79		
2796	"	"	96.41	2.73		
2797	"	Topo	91.70	8.32		
2800	"	"	88.00	12.10	trace S.	Ag, Pb.
2804	"	"	92.00	7.94		
2793	"	Ax.	95.92	3.27	trace Fe.	Ag, Pb., Ni., Zn.
2821a	"	Pendant	92.50	7.46		Ag, Pb., S
2821b	"	"	89.40	10.59	Pb., trace S.	Ag
2821d	"	"	99.22	1.28		Pb.
N-760	"	"	94.70	5.15		Pb.?
2792a	"	Clamp			Cu.	Sn.
2792b	"	"			Cu., trace S.	Sn.
2792c	"	"			Cu.	Sn.
2792d	"	"			Cu.	Sn.
2791e	"	"			Cu.	Sn.
2639	Copacabana	Topo	87.4	12.68		Ag, Pb., S., Zn.
2641	"	"	94.24	5.76		Pb.?
2642	"	"	94.07	5.21		Pb., S.

BOLIVIA (Continued).

Cat. No.	Locality.	Object.	Cu.	Sn.	Present.	Absent.
2643	Copacabana...	Knife...	90.30	9.76	.....	Ag., Pb., S.
2644	"	"	98.30	1.71	.....
2652	"	Topo...			Cu., trace Sn.	Pb.?
2752	"	Long Chisel...	93.75	6.29	.....
2645	"	Topo...	92.50	7.56	.....	S.
1846	Isl. of Titicaca	Battle Ax...	90.00	10.02	.....	Ag., Pb., S.
1806	"	Knife...	97.00	3.06	.....	Ag., Pb., S.
1807	"	"	94.70	5.29	.....	Ag., Pb., S.
2068	"	"	93.70	6.32	.....	Ag., Pb., S.
2485	"	"	93.43	6.57	.....	Pb.
2486	"	"	90.00	9.12	.....	Pb., Ag., As.
1950	"	"	96.70	2.03	Pb. 0.41	
1961	"	Topo...	89.40	10.62	trace S.	Ag., Pb.
1965	"	"	98.40	1.65	.....	Ag., Pb., S.
1998	"	"	95.80	4.13	trace S.	Ag., Pb.
1949	"	"	91.00	4.00	Pb. 6.00	
1947	"	"	99.10		.....	Sn.
2065	"	"	97.00	3.00	.....
1782	"	"	95.16	4.13	trace Pb.	
3115	"	"	92.38	3.87	trace Pb.	
3286	"	"	95.41	3.86	.....
1838	"	?	97.82	1.39	Pb.	
1955	"	"	93.67	6.35	.....
1845	"	"	97.12	1.70	trace Fe.	Pb., Ag., Ni., Zn.
1841	"	Cutting tool...		trace	Cu., trace Au.	Pb.
3037	"	Ax...	93.70	6.20	.....	Pb., S.
1952	"	Ax or Chisel...			Cu.	Sn., Ag., Pb., Zn.

TABLE II. BY DRS. MORRIS LOEB AND S. R. MOREY.

Cat. No.	Locality.	Object.	Cu.	Sn.	Pb.	Fe.	S.	As.	Density
1842	Isl. of Titicaca	Chisel or drill.....	91.81	7.56	.....	trace.....	.....	.....	8.68
1840	"	Chisel.....	90.51	8.92	.....	trace.....	trace.....	.....	8.94
1959	"	".....	95.59	4.48	.....	trace.....	.....	.....	8.92
2413	"	Drill (?).....	94.96	4.98	.....	.....	0.53	.....	8.61
1949	"	Chisel.....	91.43	7.05	.....	trace.....	.....	.....	8.18(?)
859	Chan Chan.....	Spear-point.....	97.43	.....	trace (?)	trace.....	little....	2.14	8.98

TABLE III. BY PROFESSOR S. P. SHARPLES.

Cat. no. 8710.	Ornament from Ancon.	Copper with trace of silver
" 7322.	Tool	Copper
" 8868.	Pin from Palasgache.	Copper, 89.21 — Tin, 10.48 — Iron, Silver &c., 31
" 16420.	Tweezers from Pacasmayo.	Copper, 83.21 — Silver, 16.79
" 10000.	Group of Figures. Chimbote.	Copper, 85.56 — Tin, 13.21 — Iron, 1.23

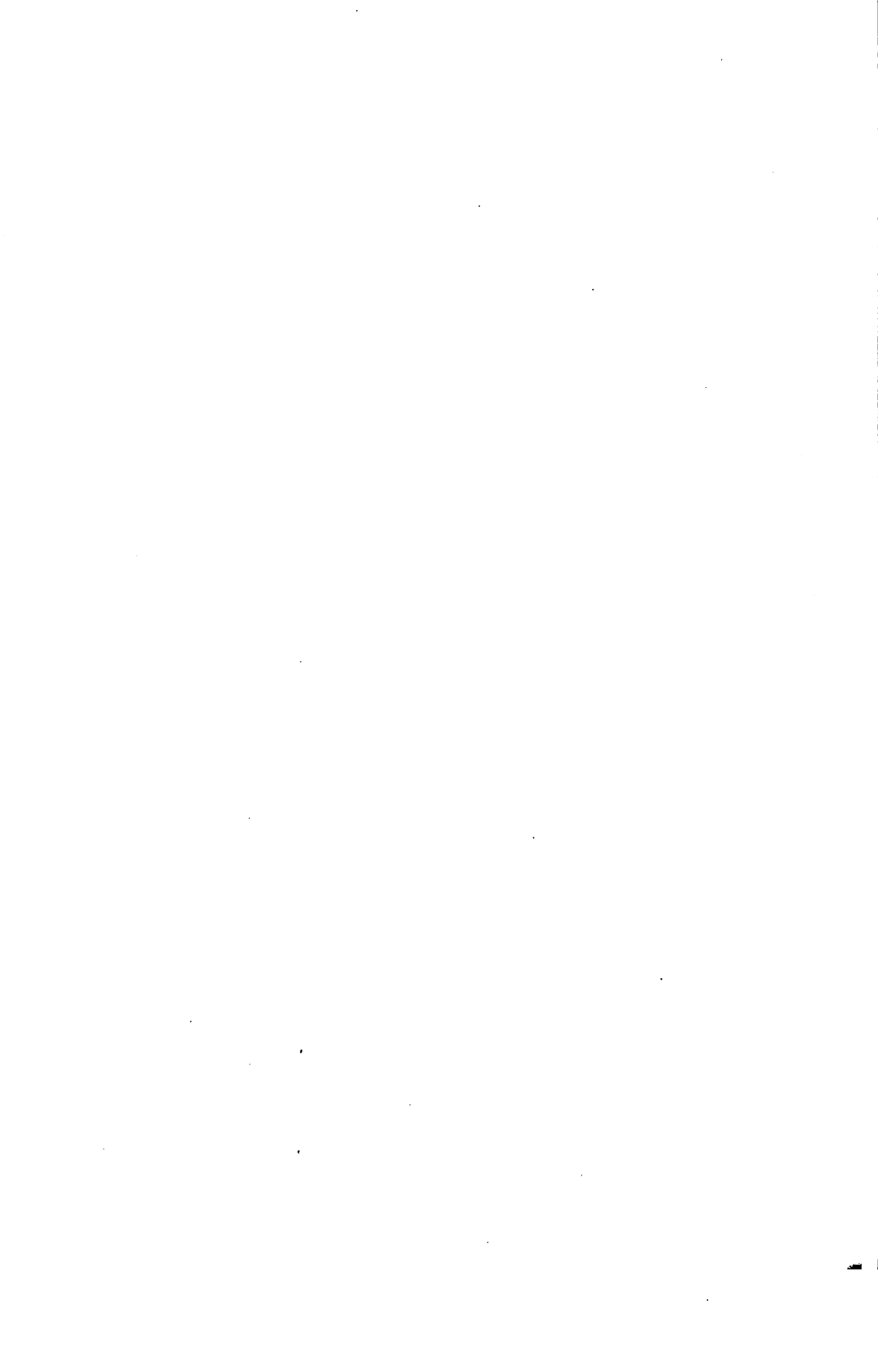


FIGURE 1.

Types of Implements from the Island of Titicaca, Bolivia.

Fig. a (1956) shows a needle, $4\frac{1}{4}$ in. long. It contains 4 percent of tin.

Fig. b (1846) is a battle ax. This form, which is not uncommon, is a modification of the six-pointed or morningstar club head, so common in both stone and metal. In this case one of the points was flattened out into the form of an ax blade. It was cast in a mould, and the blade hammered into shape. The percentage of tin is 10.02.

Figs. c, d, e (2046, 2045, 1834) are bolas, containing respectively 5, 7.26, and 2.48 percent of tin. Each has a hollow space inside with a cross-bar to which the cord was attached. The bola, as used by the Peruvians for hunting consisted of three balls of stone or metal united by thongs to a common center. One of the balls is smaller than the others, and this one was held in the hand, and the other two whirled about the head. When released a bola goes revolving through the air, and on striking the legs of an animal it winds around them, and brings him down.

Figs. f, g (1998, 1782) show topos or pins, used to hold a shawl-like garment together at the throat. In the head of these pins are perforations for cords. Such pins were often made to do double duty. The two shown here have the upper edge of the head sharpened, and were used as knives. Often the head was in the form of a spoon, and doubtless used in eating the ground parched corn, which was and is one of the favorite foods. Both pins contain 4.13 percent of tin.

Fig. h (2486) is a knife, $5\frac{1}{2}$ in. high. A portion of the blade is missing. The handle terminates in a well-formed hand. It was cast, and the blade hammered. It contains 9.12 percent of tin.

Fig. i (1839) is a chisel-like implement. Its cutting edge is at the lower end; the upper end is made larger that it might be held firmly in the hand. Such implements often have this end extended out on both sides, like the top of the ax shown in Fig. 3b. Analysis shows this implement to be of nearly pure copper.

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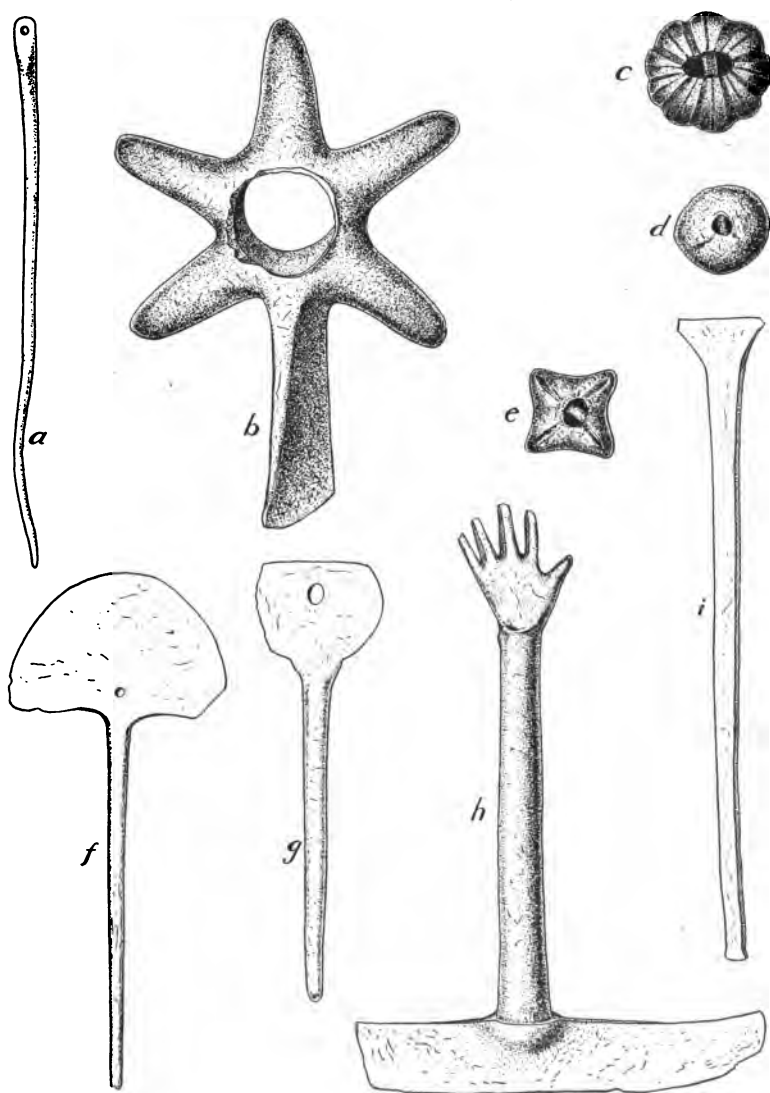


Fig. 1.

FIGURE 2.

Types of Implements from Tiahuanaco, Bolivia.

Fig. a (2797) shows a topo or pin with its head perforated for suspension. It contains 8.32 percent of tin.

Fig. b (2791a) is a common form of the Peruvian knife. The tip of the handle is missing in this specimen. The percentage of tin is 6.17.

Figs. c, d, e (2821d, 2821b, 2821a) shows a form of pendant that seems to be peculiar to Tiahuanaco, and not found at any great distance from that place. They contain respectively 1.28, 10.59, and 7.41 percent of tin.

Figs. f, g (2792b, 2792e) are copper clamps. They are used to hold the blocks of stone together in some of the buildings in Tiahuanaco, and have been found in no other locality. They are about 5 in. in length, and are without a trace of tin.

Fig. h (2794) is a topo or pin, $4\frac{1}{2}$ in. long. It is perforated for suspension, and is a good example of the double use of such pins, as its head is shaped like a Peruvian knife. The upper surface has been brought to a cutting edge. Percentage of tin 7.79.

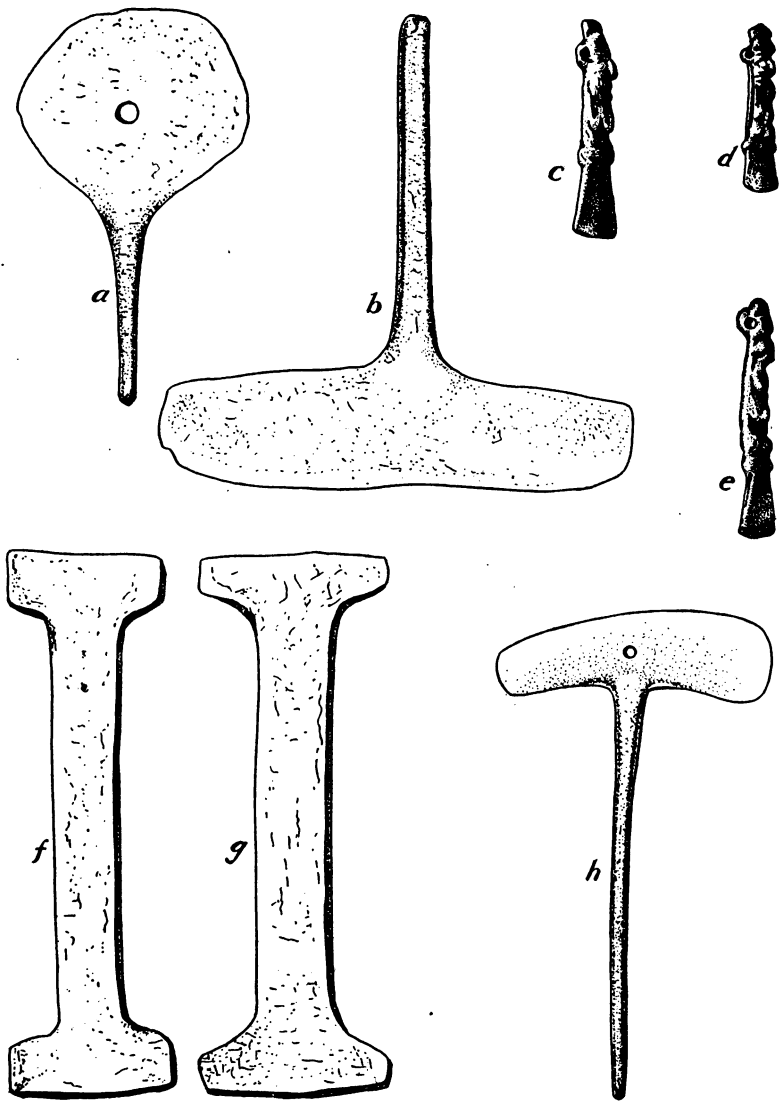


Fig. 2.

FIGURE 3.

Typical Objects from Cuzco, Peru.

Fig. a (9189). Cast figure of a llama. Such figures were buried in the fields where the llamas grazed as a prayer or charm for the increase of the flock. This specimen contains 8.54 percent of tin.

Fig. b (9188) is an ax or hatchet with the upper part extended out on both sides, which made the attachment of a handle an easy matter. It was cast and hammered, and contains 3.87 percent of tin.

Fig. c (9191) is an odd form of bola, containing 9.64 percent of tin. It was used in the same way as the balls shown in Fig. 1c, d, e.

Fig. d (9187) shows a battle ax. It is $3\frac{1}{4}$ in. high; the blade $5\frac{1}{2}$ in. long. Like the other implements described this shows plainly the marks of having been cast in a mould. The percentage of tin is 7.14.

Fig. e (9202) shows a very common form of chisel, $3\frac{1}{2}$ in. long. It is battered and turned over on both ends as if used on stone. It was cast and hammered, and contains 4.25 percent of tin.

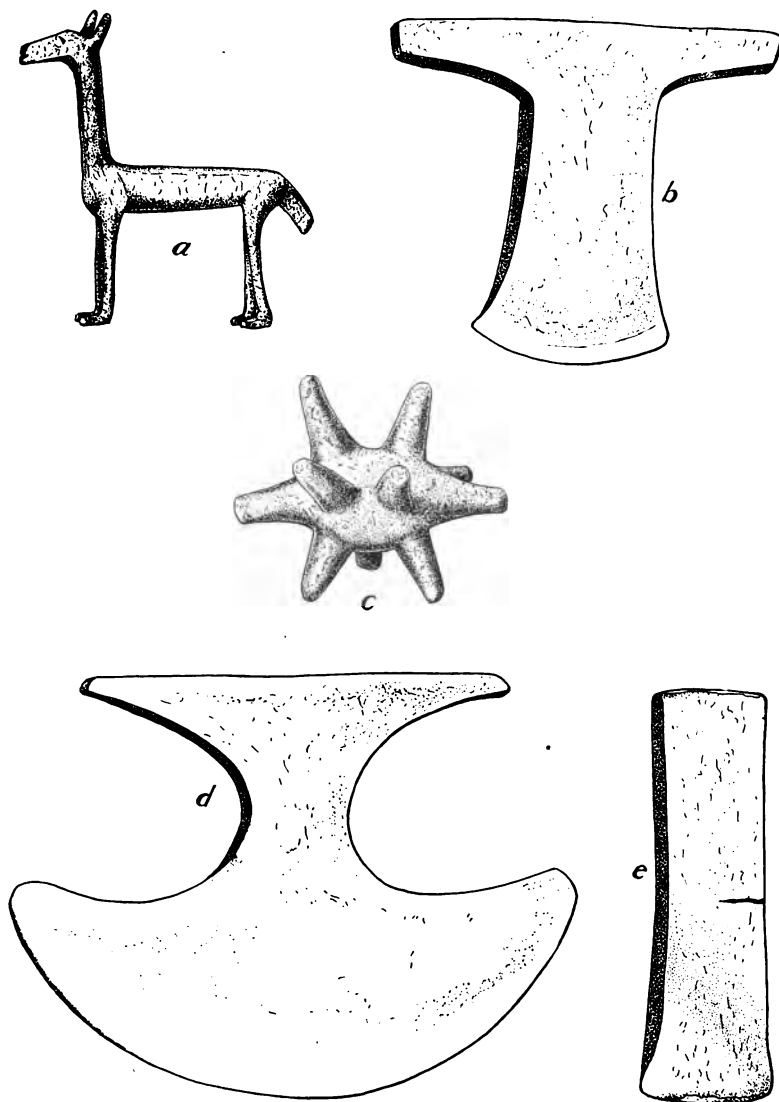


Fig. 3.

FIGURE 4.

Three fine Knives from Cajamarca, Peru. They have been cast in moulds, and the blades have been hammered.

Fig. a (9615) is $6\frac{1}{2}$ in. high, and the blade $4\frac{1}{2}$ in. long. Two human figures rest on the cross piece of the handle. This knife contains 5.67 percent of tin.

Fig. b (9196) is $4\frac{1}{2}$ in. high, the blade $1\frac{1}{2}$ in. long. The handle ends in a llama's head; a very truthful and spirited representation, and one of the most artistic castings in the collection. The amount of tin in this specimen is 5.76 percent.

Fig. c (483) is $5\frac{1}{2}$ in. high; the blade $4\frac{1}{2}$ in. long. On the cross piece of the handle, facing each other, are a man and one of the great cats. This specimen has not been analyzed.

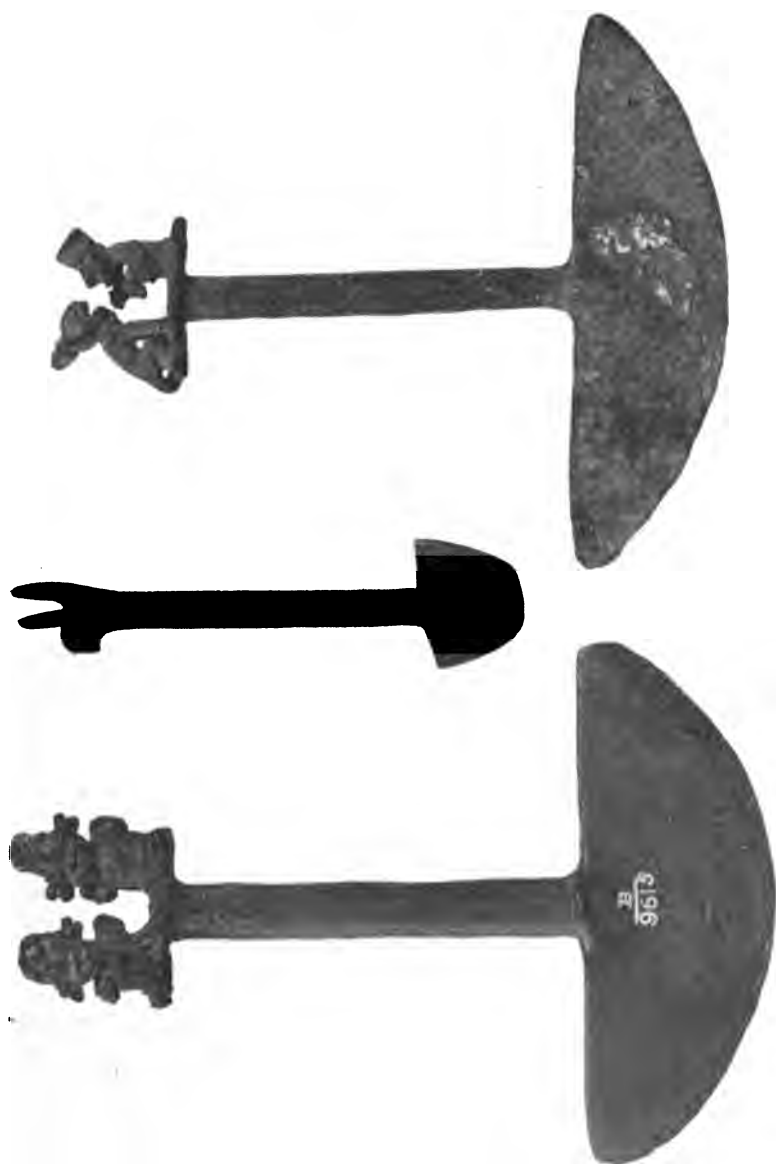


Fig. 4.

PERU AND BOLIVIA.

The implements and ornaments of bronze which have been found in such large numbers in the prehistoric burial places within the boundaries of the ancient Peruvian Empire have caused much difference of opinion and discussion as to whether the mixture of copper and tin, the component parts of bronze, was intentional or purely accidental. In other words, did the copper which they mined contain among its other impurities tin in such quantities as is found in these objects by analysis, or were the two metals separately procured and smelted together with the intention of producing a harder metal. In the following pages I propose to review such evidence as we have at the present time bearing on this question.

The early historians, Garcilasso de la Vega and Father Barba, state positively that the Indians were acquainted with the secret of making bronze. Garcilasso tells us: — "They worked with certain instruments they had made of copper, mixed with a sort of fine brass."¹ At the time the Inca historian wrote tin was often called brass, not only in South America but in Europe as well. Confusion in the names of metals is an old one for we read in Sir John Lubbock that, "In the Pentateuch, excluding Deuteronomy, bronze, or as it is unfortunately translated, brass, is mentioned thirty-eight times."²

Early in the seventeenth century the Licentiate Alvaro Alonso Barba published his "*Arte De Los Metales*." In Chapter XXXIV of this work entitled "On Metals and Artificial Metallic Articles" I find the following paragraph: —

Art also has its metals, and a multitude of manufactured metallic articles imitate the beauty of nature. From a mixture of tin and copper is made the bronze for balls, pieces of artillery and other articles. One pound of tin is taken, and from four to eight pounds of copper, according to the variety of the tin. The Indians knew of this mixture, and used it to give hardness to their instruments and arms, as we use steel or tempered iron, which were unknown to them.

Father Barba combined with his sacred duties, as priest, that of the office of director of the mines; his Parish of San Barnado being situated in the very heart of the mining district of Bolivia.

The book from which I have quoted above enjoyed a great reputation in his time on account of his attainments as a metallurgist and his knowledge

¹ Royal Commentaries, Book II, Chap. XVI.

² Prehistoric Times, 5.

of the mining industry. His intimate relations with the Indians, as priest and mine director, previous to 1639, should give great weight to his statement that the Indians knew the secret of mixing tin with copper to harden their arms and tools. Another circumstance that should be taken into account in estimating the value of his statement is the great probability that the parents of some of his Indians must have been living at the time of the Conquest, and the facts in the case well known in his day.

The edition of "*Arte De Los Metales*" published in Madrid in 1639 is now one of the rarest of books, and I have been informed that a short time ago but two copies were known to exist in South America. One of these lately came into the possession of Mr. E. P. Mathewson, the well known metallurgist and manager of the Anaconda Copper Mining Company of Montana. Mr. Mathewson knowing that I was interested in the subject of prehistoric bronze in South America very kindly loaned me the book with permission to make use of it any way that would further my studies in that direction.

During my researches I have often met with mention of Barba's work, usually followed by the remark: "not available to the author." A translation of a part of the title page will show the general character of the book. "The Art of Metals wherein is taught the true process of working Gold, Silver, Quicksilver. The manner of melting them, and how they should be refined and separated one from the other."

Chapter XXXII deals with tin, and believing that it will be of interest to the many who have been unable to see the book, I give a translation of it in full below:—

Many call white lead what we call tin, and this name is also given by those who separate Silver from Copper to the Lead that is found mixed with Silver, as will be explained further on, owing to its white appearance and to the harshness that is felt when it is bitten or broken. Common tin is produced by the same principles as Lead, but more purified and clean, from which it obtains its greater whiteness and hardness, although from the poor mixture of its pastes it is called "stuttering" and causes the harshness above mentioned. It is the poison of metals, as all that get mixed with it, will turn brittle, because by its company, the equal mixture they had before, is perverted, and their ductibility, or expansion by the stroke of the hammer, is hindered.

Only Lead is free from this disadvantage, as with its excessive moisture and softness, it is penetrated and goes on with its badly mixed parts of tin, and both remain ductile. Tin materials are not common everywhere, but they are not scarce in these rich Provinces,—Famous is the District of Collquirino, distant from that of San Felipe de Austria of Oruro, for the great quantity of very good ores that have been taken out and are being taken, for all this kingdom, among the metals of which, as has already been observed, rich pockets of silver are often found. Near Chayanta, in the Charcas there is another Tin mine, which has been abundantly worked of late years. Not far from Carabuco, one of the towns bordering on the margin of the mag-

nificent Chucuyto Lake, toward the borders of the Province of Larecaxa, there are also mines of this metal which the Indians in the time of their Incas worked and afterwards were continued by the Spaniards. The veins are large and the metals rich of their kind; from among them some ores are also taken containing much silver, and all partake of some copper, and on account of this mixture this tin is more showy and hard. The fame of the richness of these veins, induced me to visit them, aside from the desire I have had of seeing and testing the ores of all these Provinces. In the hills of Pie de Gallo of Oruro there is much tin, although not known by many, and because no silver, which all seek, is found there, they pass them by. One of the four principal rich veins that deserved the name, among the great multitude of them that are found in this peerless Potosi Hill, is the one called the "Tin Vein" on account of the great quantity it had on the surface of the land and which lower down was converted into Silver, owing to the better arrangement of the substance found.

And in the district of the Parish of San Bernardo, where I serve at present, and a quarter of a league more or less from it, there are veins of very rich tin metal, which His Excellency, went personally to inspect, on information regarding same given by me, encouraging by this, as by many other actions, those that are engaged in the working of the mines, from which so much benefit accrues to the Royal Treasury of His Majesty, and for the good of his subjects.

The localities mentioned are in Bolivia, on the shore of the great lake of Chucuyto (Titicaca) or at no great distance from it. We are told the locality of several tin mines, and that large quantities of that metal had already been taken out.

It has been observed by Boman, Verneau and Rivet, and others that the proportion of objects of copper containing tin increases from north to south, reaching its maximum in Bolivia and the high plateau region of Peru. This contention is supported by the analyses given here. In these tables we find fifty-one objects from Chepen, in the northern coast region of Peru, and of this number but five contain more than a trace of tin, and only one of these over four percent of that metal. From Trujillo, also in the northern coast region we have eight specimens none of them containing a trace of tin.

From Cuzco, in the high central plateau region, sixteen objects, all but one of which contain tin, the average being 5.50 percent.

From Bolivia seventy-two analyses showing that fifty-nine of the objects are of bronze, averaging 6.24 percent of tin.

Of the seventeen specimens from Tiahuanaco twelve are of bronze, averaging 6.50 percent of tin. The other five, which contain no tin are the clamps used to hold the stones of the buildings together. Adrien de Mortillet¹ gives the analyses of six objects from Tiahuanaco. Two of these are clamps, and have not a trace of tin, while the other four pieces are bronze, averaging 6.56 percent of tin.

¹ Paper presented at the Premier Congrès Préhistorique de France, 1905.

Of the twenty-five analyses given by Boman¹ of objects from Peru and Bolivia sixteen show tin in quantities ranging from 2.10 to 11.42 percent. None of these bronze pieces show a trace of silver.

In the table of analyses by Mr. Wissler we find eighty-three specimens of bronze and as none of these contained silver I think we may safely conclude that the alloy was cassiterite or oxide of tin.

The Peruvian bronze problem was taken up in a very interesting and instructive way by Messrs. H. W. Foote and W. H. Buell² in their investigations as to the composition, structure and hardness of three bronze axes obtained by the Yale Peruvian Expedition, under Professor Hiram Bingham in 1911.

Messrs. Foote and Buell say:—

We have determined, first the chemical composition of the axes; second, their micrographic structure, and third, their hardness. By comparing the structure of one of the axes with that of a new alloy of the same composition, we have been able to draw conclusions as to the methods used originally in making the axes.

The following results are given:—

	1	2	3
Tin	12.03	5.58	3.36
Copper	88.06	93.94	96.44
Iron	0.08	none	trace
Silver	none	0.65	none
Sulphur	0.35	0.08	0.23
Lead	none	trace	none
	<hr/> 100.52	<hr/> 100.25	<hr/> 100.03

Ax no. 1, containing 12 percent of tin, was taken for comparison as being more interesting than the others from a metallurgical standpoint. A bar of metal was cast, containing 88 parts of copper and 12 of tin, and from this a new ax was forged. It was found that this could only be done at a temperature above 500° C. and either forged hot or quenched suddenly and forged cold. If heated and allowed to cool slowly the alloy was extremely brittle and broke in pieces under the hammer.

The authors say:—

The original ax no. 1, shows from its shape and from the marks on it that it has been forged. The original shape of the casting cannot be told, but there can be no doubt that the shape has been materially changed by the forging.

In conclusion they remark:—

Taking into account the facts of micro-structure and that the ax has been forged, it is fair to infer that after casting the original alloy, it was heated to a temperature

¹ *Antiquités de La Région Andine*, Table facing p. 868.

² *The American Journal of Science*, Aug., 1912, pp. 128-132.

considerably above 500° C. and either forged hot or quenched suddenly and forged cold. This required a very considerable degree of skill on the part of the original makers.

Bolivia has for years ranked second only to the Malay Peninsula in its output of tin, and may today be the greatest tin producing country of the world. Bolivian tin is for the most part found in the form of cassiterite or oxide of tin.

Father Barba, in his chapter on tin, names Carabuco as one of the localities where the Indians had obtained this metal. David Forbes, under the heading of — Cassiterite-Carabuco-Bolivia — says: —

Tin ores occur extensively in the province of Laricaja in northern Bolivia, on the west slope of the High Andes range close to the eastern shore of Lake Titicaca, at Carabuco. They occur here associated with several minerals containing silver, and in the time of the Spaniards were worked exclusively for the nobler metal: of late years, however, the heads of these mines have been and still are worked for tin. The tin ore is in the greatest part cassiterite, which occurs crystallized in prisms, having a specific gravity of 6.4. Mr. Philip Kroeber has forwarded me the subjoined results of his analysis of these crystals.¹

Water	1.737
Tin	76.805
Oxygen	19.534
Iron	2.177
Silver	0.015
Tungstic acid	0.020
Lead	0.250

100.538

It was also an easy matter for the Indians to have collected considerable quantities of cassiterite from the sands of many of the Bolivian rivers by washing. In these sands it generally occurs in semi-rounded nodules, and is easily reduced.

The ancient Peruvians melted their ores in cylindrical pottery furnaces, called *Guayras*. Garcilasso says: —

Neither did they know how to make Files or Graving tools, or Bellows for Melting down Metals; but instead thereof used Pipes made of Copper, of about a Yard long, the end of which was narrow, that the Breath might pass more forcibly by means of the contraction. And as the Fire was to be more or less, so accordingly they used eight, ten or twelve of these Pipes at once, as the quantity of Metal did require. And still they continue this way, though our Invention of Bellows is much more easier and forcible to raise the Fire. Nor had they the use of Tongs to rake their heated Metal out of the Fire, but rather drew it thence by a piece of Wood, or some

¹ Philosophical Magazine, vol. XXX, p. 141, 1865.

Bar of Copper; with which they cast it into a heap of wet Earth, which they kept purposely by them to cool their Metal, until such time as they could take it into their hands.¹

The Museum's Peruvian collections contain two of the copper pipes described by Garcilasso. These are 31 and 25 inches long respectively. They are both made of rather thick sheet copper and have at one end a tunnel-shaped mouthpiece about $3\frac{1}{2}$ inches in diameter at the rim. This part was made separately by bending the sheet copper into the desired form and then hammering or welding the edges firmly together. This mouthpiece was welded to the tube which was made by bending the copper into the cylindrical form. In this case the edges are nicely brought together, but not welded. The outside of the tube shows how these edges were held together, for the marks of a closely wound cord of some kind are plainly to be seen from the mouthpiece to within half an inch of the end that was inserted in the clay furnace.

Dr. Daniel Wilson in his well known work on Prehistoric Man ² gives the following analyses of American bronze objects:—

No.	Locality	Copper	Tin	Iron
1	Chisel from silver mines, Cuzco	94.	6.	
2	Chisel from Cuzco	92.385	7.615	
3	Knife from grave, Atacama	97.87	2.13	
4	Knife from grave	96.	4.	
5	Crowbar from Chile	92.385	7.615	
6	Knife from Amaro	95.664	3.965	0.371
7	Perforated ax	96.	4.	
8	Personal ornament, Truigilla	95.440	4.560	
9	Bodkin from female grave, Truigilla	96.70	3.30	
No. 1. Humboldt		No. 5. Dr. T. C. Jackson		
2. Dr. J. H. Gibbon		6, 7. Dr. H. Croft		
3, 4. J. H. Blake, Esq.		8, 9. T. Ewbank, Esq.		

These scattered analyses, collected by Dr. Wilson forty years ago, are familiar to most archaeologists. While no attempt has been made to collect published analyses it was thought best to include this table, for comparison, as the names are all those of well known persons, and the figures have been so often quoted.

¹ Royal Commentaries, Book II, Chap. XVI.

² Vol. 1, p. 254, London, 1876.

ARGENTINA.

Prof. Juan B. Ambrosetti has given much time and careful study to the prehistoric objects of bronze in Argentina, particularly to those from the Calchaqui region. As this region lies just south of Bolivia, and so many of the bronze objects found there are identical in form with those of Peru and Bolivia, any information that he has collected concerning their manufacture would apply equally well to the bronzes of the region we are studying.

In his work on bronze ¹ Prof. Ambrosetti gives analyses of sixteen bronze discs. The amount of tin in these objects ranged from 1.57 to 8.67 percent; the average being 3.60 percent. These discs are of various diameters and are ornamented with embossed designs. Besides these discs he also gives the analyses of a knife, and five hatchets, containing respectively 3.80, 7.38, 6.06, 3.34, 5.73 and 6 percent of tin. These with the sixteen discs make a total of twenty-three objects analyzed with an average of 4.10 percent of tin. Whence came the tin in these objects? Prof. Ambrosetti states that there is still a doubt if that metal exists in Argentina, but quotes from the Memoirs of the National Department of Mines and Geology (1893-4) the analysis of a specimen of mineral from Cordoba reported as containing 2.16 grammes of tin to the 1000 kilos.

F. L. and E. Hess state that cassiterite has been reported near Tinogasta, in Rioja Province, in the department of Chicoana, La Poma and Province of Salta.²

Belief in the absence of tin, or at least its presence in but very small quantities, has lead some archaeologists to the conclusion that either cassiterite was brought from Bolivia or that the objects themselves were importations from that country. The latter theory is now known to be incorrect.

Dr. Francisco P. Moreno in his "Notes on the Anthropogeography of Argentina" says:— "In San Fernando and Corral Quemado I had proof that the bronze implements which are frequent in the Calchaqui graves, were not foreign, but were smelted and cast on the spot. I discovered some casts and the slag from the melting pot."³ At Antofagasta de la Sierra he relates:— "In the time of former settlements there were cornfields and irrigating channels, while among the ruins of the town, and in the black lava, I have discovered foundries, and small melting-pots and broken casts for the beautiful bronze discs."⁴

¹ *El Bronce en la Region Calchaqui*, Buenos Aires, 1904.

² *Bibliography of the Geology and Mineralogy of Tin*, Washington, 1912.

³ *Geographical Journal*, Vol. XVIII, p. 586.

⁴ *Idem*, p. 588.

Martin de Moussy,¹ quoted by Ambrosetti, states that in the Potrero Grande there are copper mines which have been worked from remote ages. That the Indians, before the Conquest, extracted the metal to make their weapons and agricultural implements; and that in the hamlet of Jagüe he discovered the ruins of rude furnaces that had been constructed by the ancient inhabitants, with dross evidently produced by fusion on the spot.

Prof. Ambrosetti figures two pieces of slag — “personally extracted from ruins during my expedition of 1896.”² One he found at Fuerto Quemada and the other at Tolombón. These were analyzed by Dr. J. J. Kyle with the following result: —

	No. 1	No. 2
Copper	96.80	95.60
Tin	1.34	3.22
Arsenic	0.40	—
Iron	trace	trace
Carbonic Anhydride	1.46	1.18
	100.00	100.00

The finding of furnaces, melting-pots, moulds for casting, and slag in the ancient ruins makes it certain that the bronzes were cast on the spot, and thus disposes of the theory of their foreign origin.

CHILE.

In Chile bronze objects, while by no means as common as in Peru and Bolivia, are found in considerable numbers and in various localities. Chile is abundantly supplied with copper, but as far as is known there is little or no tin in the country.

F. L. and E. Hess³ quote A. Götting as follows: — “Cassiterite occurs in a diabase in which are also deposits of cinnabar, siderite, copper minerals and gold. The tin is apparently not in commercial quantity.” Gilliss⁴ gives analyses of fifteen varieties of copper ore found in Chile, and not one of them shows a trace of tin.

Alfred Wilhelm Stelzner, an eminent authority says, “if we turn to

¹ Description géographique et statistique de la Confédération Argentine, Paris, 1860, tome II, p. 395.

² El Bronce en la Region Calchaqui, p. 184.

³ Bibliography of the Geology and Mineralogy of Tin, p. 55.

⁴ U. S. Naval Astronomical Expedition to the Southern Hemisphere.

Chile we find no tin mining, nor a single reliable account, even of the smallest amount of tin having been found there." ¹ Here again, as in the Calchaqui region, according to our present knowledge, copper exists but no tin, or at least in very small quantities. Did the prehistoric people of Chile work tin mines of which we are ignorant, or had they discovered copper ores containing as high a percentage of tin as the Cornwall coppers, of which nothing is now known; or did they obtain their tin from their northern neighbors? This presents one of the important historical problems of our subject to which we must now give some attention.

GENERAL DISCUSSION.

"Copper and its Alloys in Prehistoric Times," ² the subject of the presidential address of W. Gowland before the Anthropological Institute of Great Britain and Ireland, seems to me to deserve more than ordinary attention of those who are trying to solve the problems of prehistoric bronzes. His position as Professor of Metallurgy at the Royal School of Mines gives his statements much authority. Following are a few excerpts from his address: —

The camp fire was, I hold, the first metallurgical furnace. Pieces of ore which among the ring of stones enclosing the fire, or which accidentally were embedded in its embers, would become reduced to metal. The cakes or lumps so produced would naturally attract attention of primitive man, and if he attempted to fashion them, as he was accustomed in making his implements of stone, he would then become acquainted with their curious properties of malleability and toughness, wanting in his customary materials, and so be lead to apply them to practical use.

Furnaces were built in high places exposed to the wind, the air forced by a breeze through the apertures between the stones, giving rise to a sufficiently high temperature for the reduction of the metal, and no artificial blast was needed.

Then as regards the metallic ores which were within the reach of prehistoric man, they were undoubtedly those which occur at the surface of the ground, i. e., when a mineral vein outcrops or is exposed. Now the ores which occur in this part of a vein are as a rule oxides and carbonates, which of all ores are most easily reducible to metal, and from all these metals can be obtained without any difficulty whatever by treating them in the primitive "hole in the ground" furnaces we have considered.

So that when once the discovery was made that, simply by heating stones of a certain colour and weight, metal could be obtained, and when the possible applica-

¹ *Zeitschrift der Deutschen geologischen Gesellschaft*, vol. XLIX, p. 76.

² *Journal Anthropological Institute of Great Britain and Ireland*, vol. XXXVI, pp. 11-38.

tions of the metal to useful purposes were also discovered, there would be, it is certain, a large production in the localities where these stones or ores occurred. Hence the vast amount of prehistoric metal objects which have been unearthed is by no means surprising.

The localities where these oxides and carbonate ores occurred must have been the centres whence the metal or metals were supplied to others, but it does not necessarily follow that in them, or even near them, the largest number of metal objects were always made, or should always be found, for the crude metal, more especially in later times, would often be merely an object of barter and would be worked into useful forms in more or less distant places.

It had been stated by a number of authors that bronze could not be produced by smelting a copper ore containing tin ore. Among others Sir John Lubbock¹ publishes the report of Alfred Jenkin, an experienced assayer, who experimented with the tin-copper Cornish ores and writes:—

I do not think there are any Cornish ores which can be so smelted as to produce a mixed metal consisting only of copper and tin, and in such proportion as to form bronze: and for this reason, that although the ore may contain a sufficient proportion of tin, yet, as they also contain other ingredients, it would, I think, be impossible to get rid of all such ingredients without at the same time getting rid of the tin also.

Professor Gowland answers these statements by preparing a furnace of the "simplest primitive form, merely a hole in the ground." In this he smelted a mixture of copper ore (green carbonate) and tin stone, and obtained a copper-tin alloy. He says:—

This experiment proves indisputably that when a copper ore containing tin ore was smelted by primitive man, a bronze consisting of copper and tin was obtained, and affords a complete refutation of the statements that such ores will only yield copper and not a copper alloy.

We will now proceed to the consideration of the alloys, accidental and intentional, which were employed in prehistoric times. We will first consider the alloys which were the accidental result of smelting impure ore. In this category may be placed all those which contain less than about 1–2 percent of tin, although in exceptional cases a much larger percentage of tin may be accidental, as, for example, when the metal was obtained by smelting a copper ore rich in tin.

The following are some of the points made in Prof. Gowland's address:—He holds that in the early metal age the metals that are often present in copper have not been intentionally added, but are the result of smelting impure copper ore, but in somewhat later times when experience had shown that the addition of certain other metals to copper yielded a metal possessing more useful properties than copper ore alone, then these additions were made.

¹ *Prehistoric Times*, p. 608.

The term "copper" should be applied to all implements which contain 96 percent of copper and upwards, the remainder, 4 percent or less, being an assemblage in various proportions of two or more other metals, with occasionally sulphur; those containing two or more percent of tin to be excepted. That alloys containing less than about 1-2 percent of tin come within the accidental category, although in exceptional cases, as when Cornwall or other tin and copper ores were used, a very much larger percentage of tin may be accidental.

Verneau and Rivet say: —

One might object, it is true, that the presence of tin in the zones already mentioned is not intentional, that it is owing to the nature of the mineral employed. To this objection Boman answers that the only strata known here of native copper containing tin, and that in very small quantity, is that of Corocoro, in Bolivia, and if one admits that some parcels of crystals mixed with the copper ore would explain the presence of tin, in objects containing tin, this would not apply to some alloys where the metal exists in a proportion of 10 to 16 per 100, as is met with in Bolivia and the Argentine Republic. Sancho Dias expresses the same opinion.¹

Weed says: —

The Corocoro mines have been worked from prehistoric times, but the production is only known since 1879. The copper is mainly native: but arsenates and glance occur. Domeykite (arsenic 28 percent, and copper 71 percent) occurs.²

David Forbes says: —

The well-known copper mines of Corocoro (Bolivia) are situated in the red sandstone of this formation and have been worked by the Indians from time immemorial. They were found in operation at the time of the Spanish conquest, and since then, up to the present date, have gradually increased in importance, notwithstanding that many of the mining and metallurgical processes are conducted in a manner more indicative of the times of the Inca dynasty than of the nineteenth century.

The Veta Remacoia, or main seam of copper is found to produce native copper, disseminated irregularly through a coarse grit, in grains, irregular lumps, or plates, sometimes of very considerable size. This seam is considered to have been the most anciently worked deposit of Corocoro, as it had been extensively worked by the Indians before the Spanish conquest.

The formation in which the Corocoro mines occur extends from Lake Titicaca southward nearly, if not quite, through Bolivia.³

As the bronzes from Bolivia contain the most tin I considered that country the best field in the old Peruvian Empire for investigation in an

¹ *Ethnographie Ancienne De L'Equateur*, p. 333.

² *The Copper Mines of the World*, pp. 180-181.

³ *Quarterly Jour. of the Geological Soc. of London*, Vol. 17, pp. 40 and 42.

attempt to determine, as far as such things can be determined, the truth in regard to the controversy between those who believe in the accidental, and others who maintain the intentional theory of these bronzes.

Before beginning this study I had supposed it a comparatively easy matter to ascertain the composition of many of the Bolivian copper ores; but as I examined work after work on metals and mining, I became more and more astonished at the meager information they contained on this point. While I should have liked to have found analyses of a large number of Bolivian coppers, still enough information has been collected to convince me that these old implements could not have been made of a metal produced by smelting impure copper ores.¹

In his "Story of Machu Picchu"² Professor Hiram Bingham figures quite a large piece of tin which he considers as perhaps the most important of his discoveries in that ancient ruined city, and remarks: —

It has been generally supposed that the ancient peoples of Peru did not know how to manufacture bronze, but that all their bronze was accidental. This picture shows a piece of pure tin, which had apparently been rolled up by the Incas or their predecessors like a sandwich. From it, it is supposed, slices were cut when the artisan to whom it belonged needed tin in the making of bronze. It is a strong indication that the inhabitants of Machu Picchu knew how to make bronze.

In conclusion I should like to return to the subject of the copper clamps, or bolts as they have sometimes been called, from Tiahuanaco. It seems to me that in these objects we have a strong argument on the side of the intentional theory of Peruvian bronze.

Of the twenty-three objects from Tiahuanaco analyzed by Wissler and

¹ Since writing the above I have received the following letter from Mr. R. M. Atwater Jr.: —

"Replying to your letter of the 22nd instant, I wish to say that I shall be very glad indeed to give you all the information I possess in regard to Bolivian mines, and shall take an early opportunity to call on you, in order to discuss the matter thoroughly. In the meanwhile you are perfectly safe in proceeding upon the ground that there does not exist in the mines of Bolivia any natural alloy of copper and tin, or either veins or placers where the two metals occurred within such proximity that their mixture could be accidental. Any race capable of making gold and silver ornaments, such as you have seen coming from Old Peru, were equally capable of smelting tin and alloying the same with the native copper. The discovery of native copper in stream beds was easy, although, no doubt, it gave rise to much disappointment when the finder discovered that the copper was not gold. The discovery of tin, however, must have been by a different method, since tin-stone has not a metallic appearance, and crushes to powder under the hammer. The discovery of its metallic nature must have been the result of a deliberate or accidental smelting operation."

Mr. Atwater has spent much time in Bolivia, and is familiar with the copper ores and copper mining in that country. He informs me that he has made some five hundred assays and analyses of Bolivian copper ores, and that they show no tin.

² The National Geographic Magazine, Feb., 1915.

by De Mortellet, all with the exception of the seven clamps are bronze, averaging over $6\frac{1}{2}$ percent of tin. The clamps are in each case of nearly pure copper, without a trace of tin. We must believe either that these were purposely so made, or that it was simply a coincidence; if the latter it is certainly a very remarkable one. Two of these clamps are shown in Fig. 2. I can conceive of but one other theory that could be advanced to explain the absence of tin in these clamps, and that is that they are much older than any of the other objects from Tiahuanaco that have been analyzed; that they were made before the discovery of bronze. This seems to me improbable.

Too much caution cannot be exercised in accepting published statements regarding prehistoric bronze implements from Peru. Authors otherwise reliable have been known to class all copper and bronze objects under the head of bronze, without the formality of proper tests. Thus in Squier's *Peru*¹ (p. 175), four agricultural implements are figured and labeled bronze. Two of these implements are in the Museum's collection, and their analyses will be found in the table by Wissler, under the catalogue numbers of 816 and 855. They are not bronze.

Posnansky gives three plates, containing forty-eight metal objects, all labeled bronze. One of his plates shows three of the clamps, which have just been discussed, and a portion of a fourth. In his text he says: "The material is tempered bronze by a process to-day not understood."² (*El material es de bronce templado por procedimientos hoy desconocidos*). As no chemical analysis is given, we are left to infer that it was taken for granted that they were of bronze, and were so labeled.

Authors who have advocated the accidental theory to account for these bronzes have always used as their chief reason for that belief the fact that such objects as knives or chisels often contain a smaller percentage of tin than some other pieces like spoons or such pins as have no cutting edge at the upper end. This argument loses entirely its force when we inquire into the condition under which these things were made, and the behavior of copper and tin when smelted together.

Dr. A. Snowden Piggot³ in writing on the bronze statues of Alexander by the celebrated artist Lysippus, the three thousand bronze statues found at Athens by the Roman Consul Mutianus, and the many statues at Olympia and Delphi, says:

It must not be supposed, however, that the ancients possessed the skill of the moderns in the management of this metal. Having no means of ascertaining with

¹ *Incidents of Travel and Exploration in the Land of the Incas*, New York, 1877.

² *Monumentos prehistoricos de Tiahuanacu*, La Paz, Bolivia, 1912.

³ *The Chemistry and Metallurgy of Copper*.

certainly the actual composition of these alloys, they could not provide against the oxidation of the tin, and consequent refining of copper, which is one of the great difficulties in working this alloy. Consequently, analysis has shown that their bronzes are of very variable composition, some of them containing the proper quantity of tin, and others being nearly pure copper.

Indeed, this difficulty has not always been overcome in modern works. The statue of Desaix, in Place Dauphine, and the great column in the Place Vendôme, are signal instances of failure in this respect. On analyzing, separately, specimens taken from the bas-reliefs of the pedestal of this column, from the shaft, and from the capital, it was found that the first contained six per cent of tin, the second much less, and the third only 0.21 per cent, being nearly pure copper.

It seems to me that these statements of Dr. Piggot explain satisfactorily the variation in the quantity of tin in Peruvian bronzes.

Finally, taking into consideration the positive statements of Garcilasso and Padre Barba that the Indians knew the secret of combining tin with copper to harden their implements, and after a careful study of the foregoing analyses, which show that the bronze objects contain very considerable amounts of tin, especially those found in Bolivia, where it is now pretty certain that the copper ores contain no tin; the discovery of a piece of pure tin in the Ruins of Machu Picchu; the finding of smelting furnaces, slag containing tin, and moulds for casting in Argentina where all known coppers have no tin in their impurities; and such facts as can be gathered concerning the composition of all copper ores in the region under discussion, we can but come to the same conclusion as did Boman, that "We must abandon the accidental theory."¹

¹ *Antiquités De La Région Andine*, p. 866.

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